FORESTRY

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Edited by H. M. STEVEN

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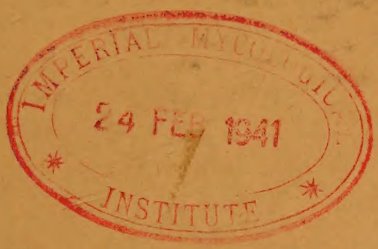

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SOCIETY OF FORESTERS OF GREAT BRITAIN

THIS SOCIETY was formed in 1925 and adopted its first Constitution at Oxford in 1926. The object of the Society is to advance and spread in Great Britain the knowledge of technical forestry in all its aspects.

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THE SOCIETY'S JOURNAL, called *Forestry*, is published twice a year, in June and December. It provides a means for the publication of the results of practice and research both in the growing of timber and in its utilization, including such basic sciences as forest physiology and ecology, forest soils, wood structure, and timber physics, and allied sciences such as forest entomology and forest mycology.

CONTRIBUTIONS may be accepted from members and others resident either in Great Britain or abroad. They should be sent to the editor, Professor H. M. Steven, 75 Fountainhall Road, Aberdeen. No article should be submitted which is being offered to any other journal for prior or simultaneous publication. Articles should be typewritten, and on one side of the paper only, and must be in a final form suitable for publication. References to literature should be collected at the end of the paper, and arranged alphabetically according to author's name, and numbered. In the text each reference should be indicated by its number enclosed in brackets. Each article should conclude with a summary. It should give the methods, extent of material, observations, and results, but should be brief and not exceed 3 per cent. of the original. It is understood that the author waives any copyright or translation rights in such summaries and that their reproduction in other publications will be permitted, subject to the source being duly acknowledged. Twenty reprints of the article will be sent free to each contributor and a reasonable number may be purchased by the contributor if ordered when the proofs are returned. The Society as a body takes no responsibility for the views expressed by contributors.

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SOCIETY'S MEDAL. The Council has resolved that the Society award a Medal from time to time to any individuals who may have rendered eminent services.

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VEGETATION SURVEY OF WASTE LAND IN RELATION TO THE ESTABLISHMENT OF WOODLANDS

(with special reference to the North-east of Scotland)

BY G. K. FRASER

(Macaulay Institute for Soil Research, Aberdeen)

ONE of the major difficulties which confronts the British forester is the decision as to whether any desired species is suitable for planting any particular area. The general appearance and the nature of the ground vegetation have, either consciously or subconsciously, formed one of the main features upon which decisions have been made in this respect. Most of the terms used in describing planting ground[1] have an application to the herbage as well as to the soil, the fundamental interdependence of which is recognized by foresters quite as much as by ecologists.

The value of certain plants as indicators of certain soil conditions is generally recognized; but in forestry the unwarranted application of this idea to a wide range of soil characters, and to plants as indicators of these, has tended to discredit the idea. It is especially misleading to suggest, as is sometimes done, that any given plant in the ground herbage is an indication of the suitability of the ground for any particular tree. (To mention one example: Garlic, *Allium ursinum*, is stated to be an indicator of Ash ground; to suggest that garlic and ash are affected similarly by climatic and soil factors is obviously absurd. The real point is that in many localities garlic is found only on moist soil derived from limestone, and ash generally does better on these than on similar non-calcareous soils, if the climate, &c., are suitable.)

Because of the many failures which have followed rule-of-thumb methods of using indicator plants, some deny the value of vegetation as an aid to the assessment of the soil, and depend upon general experience. But this itself is mainly based on contact with the ground which includes, willy-nilly, the vegetation. Others stress the importance of analysis and investigation of the soil, but this is, of course, of the future, and not an immediately practical suggestion.

Again, the ecologist transfers his belief from indicator plants to indicator vegetation, assuming that the factors of locality are expressed in a more or less definite way through the vegetation of the locality. Although this may be more true of vegetation than of individual plants, in application it is subject to similar objections to some degree. In addition this ecological concept involves considerable difficulties, for example in the interpretation of what the vegetation signifies.

[1] The word 'ground' is used here and throughout this article in place of the word 'locality' which has been unnecessarily introduced into scientific forestry nomenclature.

In the present state of science as applied to silviculture the forester must be content with a moderate degree of accuracy in choice of species. As a rule his principal species is determined by general conditions of the ground (general climate, quality of soil, &c.), as modified by commercial considerations, and the field problem is reduced to the recognition of local variations in surface conditions which make advisable a change from that species. These local changes in condition are frequently, if not always, indicated by changes in the character of the vegetation or in the soil profile and generally in both of these.

Therefore, by training himself to observe changes in vegetation, the forester is able to make use of the readily noticeable indications it presents of less easily observed changes in ground conditions (i.e. in soil and in local climate). The vegetation is thus used in the first instance not as an indicator of what may be planted but as a descriptive label of the ground on which it grows. Used in this way along with the experience obtained from past work, it enables the forester to build up his experience consciously on an accurate identification of his kinds of ground and to transmit verbally this experience to others in a way which the older generation of foresters could not.

Stated shortly, then, the aim of vegetation survey of waste land for forestry should be to establish the main floristic features of the plant communities met with, and the features which distinguish these from each other. Once established these are to be used as a means of detecting change in the ground conditions, and of indicating the more important ecological features of these changes in the ground in so far as they affect the growth of trees, and so the choice of species likely to succeed on the ground concerned.

Before describing the general lines upon which such survey work is carried out it is advisable to mention shortly the chief features of the vegetation which has usually to be dealt with. The vegetation of waste land is not wholly natural; that is to say, it is interfered with to some extent by man, for example, by felling forests, by the introduction and protection of grazing animals, and by the burning of heather. Some of the effects of human interference are drastic, at least temporarily, e.g. heather burning, others are insidious and prolonged, e.g. grazing; others are both drastic and prolonged, e.g. felling and grazing combined. Our waste land has been for the most part under the influence of these three forms of human activity for a very long period, so that it has for the most part reached what can be termed a state of natural stability under these conditions.

Thus most of our forest has been destroyed and its place taken by heather-land and grassland, with heather tending to displace grass wherever the soil surface is stable. It is necessary, however, in the field to recognize temporary change in vegetation due to more intense local effects of human interference. Usually they are fairly well recognized, e.g. those due to heather burning or recent felling of trees. But the effects of grazing are more difficult to observe and to assess. They are, in short, to conserve grassy herbage at the expense of heather. Either the heather is prevented from invading grass by having its growing-points pruned off, or it is pruned down so close that grasses,

especially tufted grasses, are enabled to spread and crowd out the heather. Grasses, on the other hand, respond to grazing by tillering and so form a closer turf in which heather does not find it easy to germinate.

Direct evidence as to the former distribution of vegetation and its character is not easy to come by. It seems likely, however, that apart from certain local types (such as sand-dune and other coastal types, lowland peat mosses, and the vegetation of hill-tops) the general vegetation consisted of what may be shortly described as the Oak–Pine–Birch–Heath or Moor sequence of plant communities, in which the lower ground is occupied by woodland and the higher by heather. The distribution and character of our present-day woodlands bear little relationship to this natural sequence, since the species (or, as in Scots pine, the varieties) used in forestation are not native to Scotland. There is little doubt, too, that for some hundreds of years the greater part of the area now covered with woodland was waste, or else was, particularly the mixed broadleaved woodland, under cultivation. It is likely that Scots pine is more abundant now and for the last two hundred years or so than it had been for something like two thousand years, especially if we except the Grampians and their lower slopes.

Nevertheless it may be concluded from a study of such remnants as can be found that the general picture of what our vegetation was is something like the following. On the lower marshy ground of the river valleys grew alder-willow scrub, with oak on the relatively drier patches and with oak-hazel scrub or woodland on fresh and moist slopes and elm forming fringes on rocky and less humose stream banks. Ash was probably confined to calcareous soils, or at least richer soils such as those of Old Red Sandstone marls and clays. It is likely that most of the low-lying badly drained ground and upland flattish areas were covered with peat, such as valley fens on the richer ground and mosses on the more acidic and poorer metamorphic rocks, and at higher elevations. On well-drained lower slopes, oak or oak-hazel woodland occurred, with oak reaching a maximum elevation of 500 to 800 feet. (Remnants may be seen at Ballater, Elgin, Darnaway, &c.) At higher elevations oak was gradually replaced by birch and pine, and at still higher elevations the pine became open and scrubby (examples not uncommon in the Grampians, e.g. Ballochbuie). Above the forest limit there was wind-eroded *Calluna* heath and hill peat moss. It is, of course, unlikely that this woodland was by any means continuous. Stretches of heather ground and wet 'moor' are likely to have replaced and been replaced by forest as climate changed. Possibly since pre-Roman times there may have been very little change on the whole, and our natural forests may have consisted of fringes of woodland along our lower river valleys extending only along streams into the uplands, apart from a few favourable sites where forest was able to maintain itself, for example, on the sandy soils of Speyside and Deeside. There is little indication that the metamorphic boulder-clays of this region have carried woodland for a very long time, and most of our surface is boulder clay. Traditional accounts of large forests are not reliable even as regards relatively recent times.

At any rate most of the lower ground was denuded of trees by the Middle Ages, and the broadleaved woodland zone at least was largely taken over for agriculture, in which the area of arable land gradually increased. Peat mosses were used up for fuel, and along with the more accessible and ploughable heather ground were brought under cultivation or at least grazed. Since the grazier has an antipathy to even individual trees (apart from the open parkland with scattered trees permitted to exist as winter shelter), our present forestable waste land consists chiefly of these treeless grazings.

The moister or fresher broadleaved woodland was succeeded by grassland in which the less robust grasses of the stream banks, those of the forest ground herbage, and of the coastal meadows, predominated. The drier broadleaved woodland, together with the mixed forest, was replaced by ground vegetation in which predominated the narrow and wiry leaved grasses common in our present pinewoods, e.g. *Deschampsia flexuosa* (Hair grass), *Anthoxanthum* (Vernal grass), *Holcus mollis* (Soft grass), and *Agrostis* spp. (Bents grass), with *Holcus lanatus* (Yorkshire fog) and *Nardus* (Mat grass) in wetter places. But on dry sites and on pine humus *Calluna* finds suitable conditions for its establishment. So in most places the dry woodland and pine forest-belt became relatively rapidly covered with heather, the chief check on which was grazing (as indicated above).

This change in vegetation is accompanied by change in soil. The mild humus of fresh broadleaved woodland is maintained at least to some extent by the succeeding grasses of the meadow types. But with increasing humus deposition at the surface, such as takes place in dry and in more acid soils, the wiry grasses and heath plants take the place of woodland, making the surface still more acid, and in turn giving way to *Calluna* which produces strongly acid humus after a longer or shorter time. Thus in our unplanted and uncultivated ground we have in place of the Oak–Birch–Pine woodland series the following chief types of waste ground vegetation:

1. *Marshland* and *reed-grassland* of river margins and the flooded parts of river and stream valleys, but this is not extensive.
2. *Wet meadow* with rank grasses and many herbaceous perennial plants.
3. *Fresh grassland* or *meadow* with the grasses of the agricultural pastures such as *Arrhenatherum* (False Oat), *Phleum* (Timothy), *Dactylis* (Cock's Foot), *Lolium* (Ryegrass), *Agrostis* spp., and *Poa* spp. (meadow grasses).
4. *Heath-grassland* (or *grass-heath*) with wiry leaved grasses and the mosses and subsidiary plants usually found in upland pine woods and *Calluna* heath, such as the *Vaccinium* spp. (Blaeberries and Cranberries), *Empetrum* (Crowberry), *Potentilla erecta*, *Luzula* spp. (Woodrush), *Galium hercynicum* (Bedstraw), &c.
5. *Calluna Heath* or '*Moor*'. (It is unnecessary to discuss the use of the term '*Moor*'. It is hereafter replaced by the term '*moist heath*' as distinct from '*dry heath*' which as used here corresponds more or less with *heath* as limited in English ecology.)

6. Sub-alpine and alpine types which are above planting limits, and include among other types *wind-eroded Calluna heath*.

From the forestry point of view, (5) *Calluna heath* is by far the most important since it covers most of the ground in the north-east of Scotland which is likely to become available for planting.

Apart from the first which may be regarded as a local type directly dependent on river or flood water, these types are general in the sense that they are to be found as a more or less regular sequence from low to high elevations whenever such sequences are possible. But within each of them there are to be found variations due to some such character as variation in altitude, in parent material, in aspect, &c., such difference being inherent in the ground itself, and appearing in the vegetation as minor changes in the herbage—e.g. in the vigour of *Calluna* or in the frequency of subsidiary plants. Of these minor differences in vegetation, one of the main reasons is difference in moisture conditions, or such soil difference as can be interpreted most directly as moisture differences, so that the most natural subdivision within the types is into drier sub-types and moister, or dry and moist groups.

In addition, other more local changes are found such as temporary or slight flushing with water; these are not inherent in the ground but are the result of external conditions, e.g. proximity to a higher water collecting area, springs, position in local depressions, &c. Amongst such locally developed external conditions excessive water is the most important, giving rise to flush vegetation where water is moving, and to peat moor and similar vegetation where water is relatively stagnant.

These two sets of variations in the vegetation of a region cannot be wholly separated from each other, but in general the division works well and the vegetation types which develop are readily distinguished. Peat moor may be used to illustrate these points. In the west of Scotland peat moor is mainly a regional type of vegetation and soil (just as *Calluna* heath is in the east). There, the soil is blanket peat moss, with *Scirpus caespitosus* (Deer grass) predominant in the vegetation. In the east of Scotland peat moor either is found at higher altitudes (hill peat) with *Calluna*, Cotton grass, and Deer grass among the main constituents of the vegetation, or is a local type produced by stagnant water in hollows and flats and showing a series of vegetational facies in which Cotton grass predominates for the most part. Of these eastern types the first is of the same rank as are the altitudinal variations in *Calluna* heath and might well be included with these; the second is of the same status as flush; it is a local type induced by water of external origin. As might be expected, in intermediately placed stations the three forms of vegetation they carry tend to become identical, so that sometimes it is not practicable to separate them vegetationally. Similar cases may occur both with vegetation and with site conditions, including soils. Therefore, any rigid correspondence between soil and vegetation is not to be expected, either as between soil type and vegetation type or as between the areas which they cover.

On these lines it is found that *Calluna* heath vegetation can be divided into the three main groups of

1. Dry heath.
2. Moist heath.
3. Wet heath (or sub-moorland).

Corresponding terms which might be found more acceptable are

1. Heath.
2. Moor.
3. Shallow peat moor.

These groups are separated on the basis of variation in vegetation which they show. Certain heath plants as a rule are found more abundantly on wetter ground, others on drier. Many are common enough on both sites, but show differences in vigour and habit on different sites.

The following lists indicate the two groups of plants which come readily to the mind in this connexion:

Dry Heath Plants.	*Wet Heath Plants.*
Erica cinerea	*Erica tetralix*
Arctostaphylos Uva-ursi	*Juncus squarrosus*
Luzula pilosa	*Luzula multiflora*
Anthoxanthum odoratum	*Nardus stricta*
Agrostis spp.	*Molinia caerulea*
Veronica officinalis	*Scirpus caespitosus*
Antennaria dioica	*Eriophorum spp.*
Leontodon autumnale	*Carex spp.*
Trientalis europaea	*Pedicularis silvatica*
Thymus serpyllum	
Hieracium Pilosella	
Mosses.	
	Aulacomnium palustre
	Fissidens taxifolius
Hylocomium splendens	*Hylocomium loreum*
Hypnum cupressiforme (on ground)	*Hypnum schreberi*
	Polytrichum commune

Three of the most readily recognizable types of dry heath can be called (1) *the Calluna–E. cinerea* type; (2) *the Calluna–Vaccinium myrtillus* type; and (3) *the Calluna–Arctostaphylos* type.

1. Where *Erica cinerea* is the most abundant subsidiary plant along with *Calluna*, the ground is fundamentally dry; usually because it is stony, or gravelly, or sandy, that is to say, it has good underground drainage. Stony boulder clays on flat ground are not as a rule well drained, and therefore do not carry this type. When burnt over the *Erica* recovers very quickly and so in the flowering season burnt patches are bright purple with its flowers, and even when mixed with *Calluna* it gives the ground the purple appearance so common on old scree slopes, slaty hill-sides, and well-rotted granites. The berried heath plants are usually quite common and heath grasses may be common and become quite noticeable in burnt patches.

2. *Calluna–Vaccinium myrtillus* type. Where brashy rock is near the surface,

i.e. where wet periods alternate with very dry periods, the blaeberry becomes co-dominant with *Calluna*, and after burning over remains dominant for some time. Usually the plants are not very vigorous and fruit is small, and not very abundant. A very common position for this type is at the rock outcrops where the hill plateaux fall steeply into river valleys; on rocky ridges and thin screes in the tracks of old springs and flushes, and on such-like sites.

3. *Calluna–Arctostaphylos. Arctostaphylos Uva-ursi* is commonly found on two sites, the common factor of which appears to be inability of other plants (i.e. *Calluna*) to give good ground cover. Thus it is common in the wind-swept *Calluna* zone above the planting limit where *Calluna* is short and open, and on rocky slopes in general in the highland region. This is not the ground referred to here. It is found in its greatest abundance on dry soils with unstable surfaces at lower elevations. Here *Calluna* is ragged and open (though not short) because, presumably, of creep movements of the soil, and below and between the *Calluna* 'besoms' is found an almost continuous cover of *Arctostaphylos* wreaths. When burnt over the *Arctostaphylos* becomes dominant. Since the soil surface is unstable, there are many subsidiary plants.

4. Another type of heath which may be regarded as intermediate between moist and dry types is termed *Calluna–Deschampsia–Myrtillus*; since in addition to *Calluna*, *Deschampsia flexuosa*, and *V. myrtillus* are the most common ground plants. *Calluna* is in the form of tufts or mounds with the hair grass, berry shrubs, and most of the common heath grasses and mosses covering the rest of the ground. This type is very like the ground herbage of open birch wood and of recently felled coniferous woodland on fairly fresh slopes. It is possible, therefore, that it is a persistent relict of woodland felled not so very long ago. Its persistence may be due to grazing, but is at least in part due to the nature of the ground. It is more common on north and west aspects, and on somewhat steeper ground on the sheltered lower slopes of valleys; often it is intermediate in position between grass-heath and heath. Where the ground is wetter and the soil is covered with *Calluna* raw humus it is replaced by the *Calluna–Deschampsia* type of moist heath.

The moist heath type may be separated into two, with in addition a third intermediate type leading to sub-moorland.

5. *Calluna–Deschampsia moist heath* is found on moist ground, usually at lower elevations or at least in places which are not strongly exposed to temporary drying. It is sometimes rather difficult to distinguish this type, since the *Deschampsia* may be completely dominated by *Calluna*, and usually other subsidiary plants are at least as noticeable as *Deschampsia*. *Erica tetralix* is usually frequent or abundant, *Anthoxanthum*, *Juncus squarrosus*, *Carex binervis*, and other plants are common. But careful examination shows the presence of abundant but submerged plants of *Deschampsia*, and when the ground is burnt over these vegetate rapidly and form an almost close cover of tussocks, which remain dominant for years.

6. The other main type of moist heath, perhaps the most widespread and possibly requiring further subdivision can be called the *Calluna–Vaccinium*

moist type. The vegetation is almost entirely *Calluna* with here and there open patches of moss- and lichen-covered turf. In these patches and below the heather both *Vaccinium* spp. are found as stunted twigs. Along with the *Calluna* and sometimes spreading into or over the opener spaces are found *Erica tetralix*, *Empetrum nigrum*, and less often *Erica cinerea* and *Arctostaphylos*. Club-mosses (*Lycopodium* spp.) are common and *Hypnum schreberi* and *Hylocomium splendens* are the commonest mosses.

7. *Calluna–Nardus moist heath* is wetter than the other two and some of the examples are definitely peaty. A general note on the distribution of *Nardus* is advisable. As a rule *Nardus* is not frequent except on mineral soils and shallow peat. As heath ground becomes wetter *Nardus* becomes more abundant and its abundance on any type is increased by grazing. Snow cover also seems to have some effect since on places where snow persists into the late spring (by forming wreaths or cornices or in hollows, especially on north aspects) *Nardus* is often abundant. In the heath type, local abundance of *Nardus* usually indicates either flushing with peaty drainage or intermittent waterlogging through bad run-off. Local patches of *Nardus* due to such causes are not included in this wet heath type, by which is indicated the considerable areas of moist ground, often with poor surface drainage in which *Nardus* is frequent and abundant amongst *Calluna*. These are usually found on north and west gentle slopes and hill plateaux, on compact boulder clays, and in transition zones between drier types and peat moss. *Calluna–Nardus* is also found on the very similar conditions produced by skinning hill peat, and on reverting old arable land of the wetter types where its abundance is due at least in part to previous grazing. Along with *Nardus*, *Erica tetralix*, *Juncus squarrosus*, sedges, and sphagnum become common and *Hypnum schreberi* is the most frequent moss.

Local types of vegetation in heath consist chiefly of (8) sub-moorland and (9) flush types, under each of which there is a great variety of vegetational sub-types.

8. *Sub-moorland types.* By sub-moorland is meant here such local types of ground in heath or moor as carry quite thin peat or peat-like raw humus, and a moorland vegetation. The soil conditions indicated are (*a*) strong leaching, i.e. washing out of nutrients so that the ground is infertile, and (*b*) extremely bad aeration because of at least intermittent water-logging and consequent puddling of the soil with sour drainage. Obviously the intensity of such action is bound to vary, and therefore one would expect a considerable corresponding variation in the herbage shown by such ground. Slight waterlogging in heath, especially on boulder clay soils, may be indicated only by the appearance of *Nardus* along with some sedges (e.g. *Carex panicea*) or cross-leaved heath. With stronger waterlogging *Eriophorum vaginatum* and *Sphagnum* spp. appear and the vegetation may show signs of zonation. For example, an outside ring of *Nardus* in short *Calluna*, next a zone of *Juncus squarrosus* and creeping *Erica tetralix* in mixed sphagnum and *Hypnum* mosses, then *Eriophorum vaginatum* where water tends to be permanent, forming a bank within which in a pool

of water grow floating mosses, *Eriophorum angustifolium*, &c. But, as mentioned, the details vary much. Other plants which should be mentioned as indicating the likelihood of such conditions when found in patches and depressions in other ground are *Scirpus*, *Narthecium*, *Rhyncospora*, *Schoenus*, mosses like *Aulacomnium palustre*, *Hypnums* of the *Harpidium* group, compact *Sphagnums* and lichens (*Cladina* and *Cetraria* spp.). In lower and more sheltered sites and in contact with better soils there may be a mixture of many of the general moss and marsh plants, and distinction from the poorer types of flush may be difficult. Small areas of peat which develop from such types of ground or from flush (especially poorer types of flush in heath ground) may also be regarded as sub-moorland.

9. *Flush types.* Where the ground is regularly irrigated by moving water the vegetation usually shows distinct differences from that of the adjacent ground. Such ground and vegetation is called *flush*, and can as a rule be recognized from its topographical position, e.g. on hill slopes below collecting areas; in the floors of valleys; in outwash fans and below the spring levels, often spreading out fan-wise to the lower ground. Slight flushing on better soils, especially from below, tends to produce meadow-like vegetation, for example *Deschampsia caespitosa* meadow.

In heath one of the commonest effects of intermittent flushing is to increase the amount of grass and reduce the amount of heather; at higher elevations *Nardus* displaces heather, at lower *Deschampsia*, *Agrostis*, and *Anthoxanthum*. With stronger flushing marsh vegetation may appear, at low elevations reed-grass or tall grasses, iris, and so on; rushes, especially *Juncus articulatus*, are most common in many places, and in the more mountainous districts *Molinia caerulea*. The subsidiary plants are those of wet ground, e.g. various sedges, rushes, willow herbs, parnassia, hydrocotyle, angelica, valerian, marsh thistles, orchids. The mosses are exemplified by *Hylocomium squarrosum*, *Thujidium tamarascinum*, *Mniums*, and the larger-leaved *Sphagnums*. Bracken should be noted also, since it is very frequent as a marginal plant round strong flushes and often indicates slight flushing when it appears in *Calluna*-heath ground.

Reference should be made to the indications given of special soil conditions by the presence of less common plants. In this region these special conditions are often associated with spring flush. The presence of iron, lime, or magnesia in unusual quantity is often indicated by the abnormal habit of plants (e.g. short sedges), varieties of *Euphrasia* and of *Sphagnum*; the presence of plants like *Juncus nigritellus* and *Schoenus nigricans* is very frequently associated with iron flush. *Sanicula europaea* and *Allium ursinum* are rarely found in this area outside of the influence of calcareous rock. The mosses *Hypnum sarmentosum*, *H. stramineum*, &c., are rarely found except in abnormal conditions of the soil solution in lime or magnesia, which may make deep drainage essential before coniferous crops can be expected to grow. Lack of space prevents further discussion of similar points which arise during any survey work.

The method by which these ideas are applied to survey will now be very briefly indicated. It cannot, of course, be over-emphasized that familiarity with our plants is essential for detailed survey, but after a point such familiarity is acquired rapidly in the course of the work.

Unless the surveyor is familiar with the main features both of ground and of vegetation in the area to be surveyed, the first essential is to get the general 'feel' of the ground by making a reconnaissance survey of the whole. In this preliminary survey are noted at as early a stage as possible the major features of the ground and major similarities and differences in the vegetation from

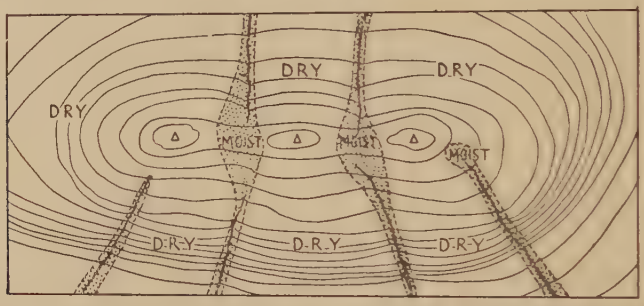

Diagram 1. Convex contours, with broad bands of dry ground alternating with narrow bands of moist or wet ground (shaded).

place to place. For example, in traversing the middle slopes of a valley it is usually found that repetition of topographical features is accompanied by repetition of vegetational facies (appearance). To illustrate: in convex contours we find on the whole wider areas of drier ground alternating with narrower areas of moister ground in which there may be a central flush. Where the contours are convex then the opposite holds—dry narrow ridges alternating with wide moist stretches in which flushes are frequent, and the lower parts of which may be continuous flush. Typical examples are shown in Diagrams 1 and 2.

Similarly, across the contour can be observed the general effects of increasing altitude and of variation in the altitudinal profile (Diagram 3). In a traverse like this several points should be looked for, e.g. gradual changes in vegetation not due to change in gradient but to altitude alone. These are, for example, shown in the height growth of *Calluna* and in its density as well as in change of subsidiary plants. The increase in depth of raw humus with increasing altitude until peat becomes frequent, and the subsequent fall in depth of humus at still higher elevations, are fairly regular features of our hills and are accompanied by changes in vegetation, say, from meadow grasses, to heath grassland to dry heath, moist heath, peat moor, and finally wind-eroded *Calluna*-heath in which *Calluna* is at first pruned short and is open, with shallow humus, and finally occurs only in patches, building up humus at one side while erosion to the mineral soil takes place at the other.

Diagram 3 is intended to show some of the frequently occurring features

of hill slopes. Peat deposition on terraces and on plateau edges where peat is often subtended by water-eroded rocky or stony slopes with a mixture of flush, heath, moor, and rock plants. Long flattish slopes usually carry moist

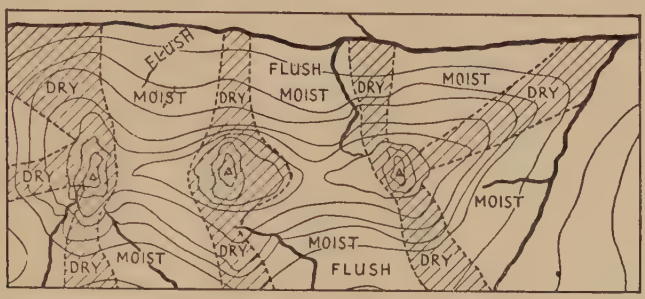

Diagram 2. Concave contours showing broad bands of moist ground, alternating with narrower ridges of dry ground (shaded).

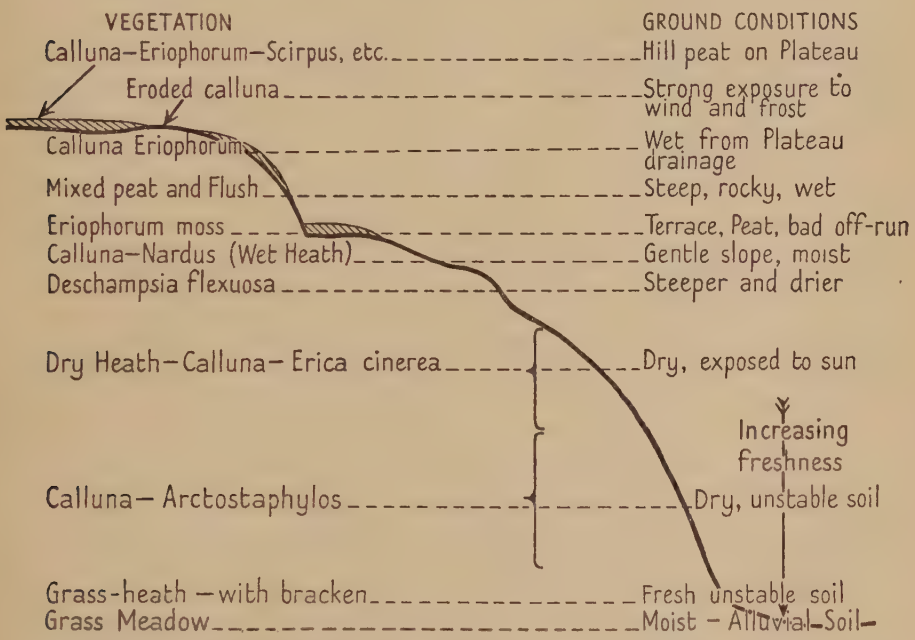

Diagram 3. Transect from high to low ground, showing common types of vegetation which may be found on typical sites and elevations.

heath, but on south aspects may bear dry types. Lower steep slopes which usually show instability of soil carry on south and east faces dry heath types changing to grass-heath or grassland towards valley bottoms; on colder aspects moister types such as *Calluna–Deschampsia* or *Deschampsia* grass-heath are more usually found. While following out such general correlations, the major variations in the vegetation crystallize out in the mind as definite

units. For these units we have used the general term type in order to avoid entanglement with the complexities of ecological nomenclature.

During further detailed survey, lists are made of the plants forming the communities and of their frequency and, if noteworthy, of their habit and vigour. The use of mathematical estimations of frequency (e.g. percentage cover or mean percentage frequency in small areas, &c.) is not attempted because of the time it involves and of the unwarranted assumption of accuracy it is apt to foster. In reducing series of lists to one composite list of the type, judgement rather than rule-of-thumb methods of inclusion or rejection of infrequent or casual species should be adopted. While lists are being compiled, original ideas as to types and their relationships are confirmed and modified and the types observed can be sorted into groups. At the same time the closer study may bring out new features of difference in vegetation which may be linked up with less obvious ground differences.

Finally, where soil survey is also being carried out the two surveys are revised together and a final estimate of the planting value of the ground can be deduced from the data established in the light of past experience of the requirements of our crop plants.

SOME FOREST SOILS OF THE NORTH-EAST OF SCOTLAND AND THEIR CHEMICAL CHARACTERS

BY ALEX MUIR

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THE various soils encountered in forest areas in north-east Scotland, although fitting into a general world-classification, have to be separated into smaller groups in order that their relationships and properties can be studied in greater detail and then correlated with their parent materials and the vegetative cover.

The usual soil investigation falls naturally into two parts: (*a*) field study, with or without detailed survey, including descriptions of site factors (i.e. parent material, topography, drainage, &c.); (*b*) laboratory examination, during which it is possible to obtain some knowledge of the content of plant nutrients and the degree to which the soil has been weathered. This second aspect of soil investigation has an important bearing on soil classification and frequently assists in putting doubtful types in a definite group.

THE SOILS AND THEIR FIELD RELATIONS

The Podzol. This is probably the commonest mineral soil type in the north-east of Scotland. It is most frequently encountered on the drier *Calluna* heaths where the parent materials are derived from rocks such as granites and their associated drifts. The site is well drained and usually flat to gently sloping, but if the parent material is poor a soil with almost all the characters of a podzol may be formed on a relatively steep slope.

The name podzol is derived from a Russian word meaning ashes, and the principal field characteristic of the soil is the ashy-grey layer that lies just below the surface organic matter. The nature of this organic matter is also of importance and in the podzol is almost invariably what is called raw humus or mor.[1]

The following description of a podzol from a mossy pine wood near Strachan, Kincardineshire, is typical.

A_0	0–5 cm.	Dark brown fibrous raw humus.
A_2	5–25 cm.	Light grey to white sandy loam, moderately compact, dry.
B_1	25–45 cm.	Rusty-brown loam, moderately compact, damp.
B_2	45–85 cm.	Brownish-fawn gravelly coarse sandy loam, very compact.
C	85 cm.+	Light fawn gravelly sandy loam; stones all pink granite.

The letters applied to the various layers are simply a shorthand notation, but are now used throughout the world. In general A denotes the eluvial

[1] See G. R. Clarke, this journal, 1935, ix. 42.

(leached) horizon, B the illuvial (accumulation) horizon, and C the parent material of the soil.

Depending on the depth and degree of bleaching of the A_2 horizon the soils are called weakly, medium, or strongly podzolized. The word podzol itself is usually reserved for the most strongly developed type and is exemplified by the Strachan soil described above.

The appearance of a podzolized soil suggests that there has been a transference of material from the upper mineral layer to those below, and when the soil is examined in the laboratory this is readily confirmed (*vide infra*).

In the earlier stages of its development the bleaching in the podzol may not be visible although brought out by laboratory examination. At this stage the soil is known as a concealed podzol. Interesting examples of this type in a highly developed state have been found on basic igneous rocks. The soils have quite a thick raw humus covering, but no sign of bleaching can be seen even although a definite hard pan is present. This is presumably owing to the absence of quartz from the soil. Chemical analysis at once shows the soil to be podzolized.

Gleying and Gley Soils. While the podzolized soils have good drainage, some or other site factor may result in a certain amount of waterlogging in part of the profile. There is, of course, a limit to the amount of waterlogging that can be permitted within the limits of the definition of the podzol, the limit being that the water-table must not be above the C horizon. Whenever the waterlogging occurs above this level the soil becomes a *gley* soil. Gley is another Russian word and describes the bluish, greenish, or grey layers or spots seen in a wet soil. As a rule there is a certain amount of rusty-coloured mottling associated with the other colours.

Waterlogging may be divided into two kinds: (*a*) surface wetness, and (*b*) ground-water effects, but both kinds may affect the one soil.

Gley Podzols. These soils are waterlogged in the lower layers and the effect may not be noticed in a cursory examination of the surface soil. The following example was described in the Bin Forest, Aberdeenshire, the property of the Forestry Commission:

A_0	0–5 cm.	Brown *Calluna* raw humus.
A_2	5–6 cm.	Dark grey loam lightens on drying.
B	6–20 cm.	Brown loam with grey spots.
B_2	20–40 cm.	Brown loam with yellowish staining.
C	40 cm.+	Light brown light loam with slight rusty and grey mottling.

This soil is only slightly podzolized as a result of the parent material being fairly rich in lime. As a rule raw humus is only found on such a soil when the ground-water table lies below the B horizon. If it should reach a higher level, as it frequently does, the surface organic layer changes into peat.

Peaty Podzols. This is a very common type at higher elevations in the north-east and is usually associated with the wetter types of heath and with moorland vegetation. The gleying in this type is often only in the upper mineral layers and seems to result from the development of the peat. Iron

pan is often associated with this soil and is illustrated in the following example from Clashindarroch Forest, Aberdeenshire, the property of the Forestry Commission. The vegetation is of a moorland type (possibly eroded peat) and the parent material till derived from slaty rocks.

A_0	0–20 cm.	Black peat.
A_2	20–27 cm.	Brownish-grey fine sandy loam, lightens on drying.
B_1	at 27 cm.	Thin, but very hard, iron pan. Roots form mat on surface.
B_2	27–57 cm.	Yellowish-brown fine sandy loam, many old root-holes.
C	57 cm.+	Fawn fine sandy loam.

This soil is wet only above the hard pan, whose formation was intensified as a result of the development of the peaty cover.

Where peat formation has taken place on a gley podzol it is sometimes difficult to differentiate the soil from a peaty gley in the field, but chemical analysis can usually settle the point. As an example of a peaty gley the following may be quoted. This soil was described on a part of the Bin Forest. It is derived from a mixed drift overlying schists and bears diffuse flush vegetation.

0–5 cm.	Dark brown peat.
5–10 cm.	Dark olive grey loam.
10–20 cm.	Light olive grey loam.
20–110 cm.	Greenish to bluish-grey loam with rusty spots. Water at 50 cm.
110 cm.+	Green loam with bluish tinge; probably churned-up rotten rock.

The typical gley colourings are well displayed in this soil. There is a certain amount of bleaching visible in the upper layers, but no evidence at all of any subsequent accumulation of any leached material. This latter feature is characteristic of most of the strongly gleyed soils.

Surface-water and Ground-water Gley Soils. These terms have been applied to certain well-defined gley types which have a mull humus surface,[1] although the surface-water type may at times tend to be somewhat humose and approach very closely to a flush-peat type. The vegetation types associated with these two soils are quite distinct, even in the non-humose varieties.

The following description of a surface-water gley was made on the Clashindarroch Forest, where it is associated with a flush (humose) vegetation and overlies slates.

0–20 cm.	Dark, almost steel-grey, sticky loam.
20–40 cm.	Medium grey loam, compact, free water base at 40 cm.
40–60 cm.	Same but with rusty mottling, compact, sodden.
60 cm.+	Brownish fawn compact loam with blue-grey and rusty mottling; moist.

No water table was reached at 1 metre. In other cases the ground water may stand so high that the whole soil is waterlogged, but the character of both soil and vegetation is determined by the free flow of water through the surface layers.

The ground-water gley soil is also known as a meadow soil since it is of

[1] G. R. Clarke, loc. cit.

frequent occurrence in low-lying alluvial meadows. The following example was described in the Clashindarroch Forest, and was derived from till overlying slates and bore a grass-meadow vegetation.

0–12 cm. Brownish-grey sticky loam.
12–24 cm. Lighter in colour, more compact.
24–70 cm. Greenish-grey loam with rusty spotting, compact.
70 cm.+ Same, but with rusty and fawn mottling.

In this particular example the ground water appears to stand fairly high throughout the year, but in certain alluvial soils there may be a considerable drop in ground-water level during the summer months, and the upper layers are then better aerated.

The Brown Earth. This type is also known as the Brown Forest Soil, but since in many areas of the north-east of Scotland where the type occurs there is no direct evidence of forest having occurred within recent times, the more general name is to be preferred. The most characteristic feature of the brown earth is its uniformity of colouring down the profile, although the colour is not necessarily brown (effect of parent material). In practice it is desirable to have some knowledge of the chemical features to make the definition of this type satisfactory. These will be dealt with later.

Two main varieties of brown earth have been identified in the field: (*a*) the brown earth proper which occupies flattish to gently sloping sites, and (*b*) the creep soil which is associated with moderately to steeply sloping sites. The vegetation varies somewhat, depending on the general elevation of the site (above O.D.) and on the nature of the parent material as reflected in the soil.

The brown earth in the north-east of Scotland is found mainly on basic igneous rocks (e.g. norite) and the following description is typical. The soil is from the Insch district of Aberdeenshire and was the site of a Scots pine wood that had been cut some time previous to sampling.

0–15 cm. Greyish-medium brown loam, crumbly, earthworms present.
15–30 cm. Same but somewhat lighter, crumbly.
30–90 cm. Brown light loam, fairly compact.
90 cm.+ Rotten rock (norite).

Although, as will be seen later, such soils can be surprisingly acid, the presence of earthworms in the upper layers is characteristic and there is little doubt that they contribute considerably to the uniformity of the soil profile.

The creep soil occurs in many parts of the hillier regions over all kinds of rocks and with various types of vegetation. The following example from the Clashindarroch Forest is typical. It overlies slates covered with hill-wash (colluvium) and bears a dryish grass-heath with whins.

0–25 cm. Greyish-brown loam, cloddy structure, worms present.
25–60 cm. Fawny brown light loam, slightly more compact.
60 cm.+ Merges into fawn sandy loam, compact.

This kind of soil is of frequent occurrence under birch wood on dry slopes in many parts of the country. When the vegetation is a little more heathy

a thin yet quite definite raw humus layer is found, but earthworms are as a rule still present.

Where the hill-wash overlies very compact till, drainage may be impeded and evidence of gleying may become visible. Impeded drainage varieties of the brown earth may also occur, but as in the case of the podzols the water-logging must be at some depth from the surface, otherwise the soil will fall into another group.

CHEMICAL CHARACTERISTICS OF THE SOILS

Data on some of the soil types just described have already been published in this journal, but in view of the useful comparisons that can be made with other types a certain amount of repetition may be permitted.

Before discussing the various soils it may be helpful to give a brief outline of the various methods used in the laboratory. In the early days of soil investigation all the determinations were carried out on the total soil, but it is now known that more valuable data can be obtained by working with a fraction of the soil only, e.g. the clay. This is separated from the soil by sedimentation and subsequently analysed for its content of silica and iron and aluminium oxides (sesquioxides). Molecular ratios of these constituents are then calculated and can be used to show the degree of weathering and leaching of the soil. Another valuable determination is that of the adsorbed or exchangeable bases, i.e. the lime, magnesia, potash, &c., held on the surface of the clay particles. These bases are leached out with an ammonium acetate solution and then determined either chemically or spectrographically, the latter method being more rapid and providing more complete information than could be readily obtained chemically. A determination of exchangeable hydrogen which is in part responsible for the degree of acidity of the soil is also made. pH values which provide a measure of the acidity are determined by an electrometric method. Still connected with the clay fraction, or certain constituents of it at least, is the use of Tamm's oxalate solution to determine what Tamm has called the inorganic gel complex. This method is only suitable for very sandy soils since the solution attacks the finer material to some extent. It is not used much in this country since the data from the clay fraction is of more general use in soil classification. The amounts of lime, magnesia, potash, &c., readily available to plants are given by the values for the exchangeable bases. The readily soluble phosphate is determined in a dilute acetic acid extract.

In the various tables which follow values for loss on ignition and total clay content are given. The loss on ignition, which is determined by igniting a weighed quantity of soil and then reweighing, may be taken as a rough measure of the amount of organic matter in the soil. When the clay content is high, no more than possibly a half of the loss on ignition represents organic matter. The data for the clay content are obtained by sedimenting the soil. The values are of use when the variations in content of exchangeable bases are being considered. Data for the contents of carbon and nitrogen are at

times obtained, but since it is difficult to make use of these figures they are not discussed. Examples of the kind of data obtained in the laboratory may now be given and their interpretation discussed.

The field characteristic of the podzol was stated to be the presence of the strongly bleached layer, and in the laboratory it can be readily shown that this bleaching is actually due to the loss of iron and aluminium which are deposited in the B horizon just below. A complete chemical analysis of the various layers may be made, but the silica/sesquioxide (SiO_2/R_2O_3) ratio brings out the feature much more clearly, as can be seen from Fig. 1. In using these

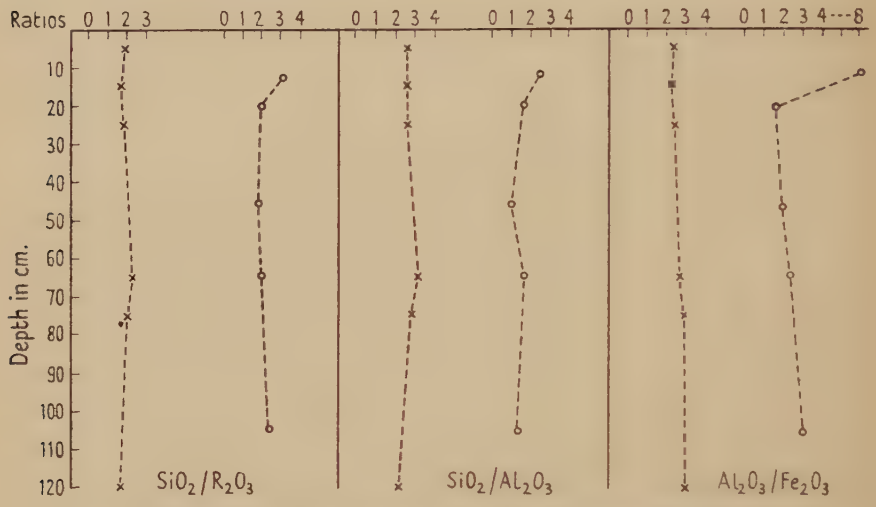

Fig. 1. Comparison of Clay Ratios in Brown Earth (×) and Podzol (o) Soils

ratios it is assumed that the silica is not transported at all, but of course this is not strictly true. It does so happen, however, that the residual products of the weathering of the soil clays in our district are highly siliceous and the ratios can therefore be used to show the degree of weathering. The wider (or larger) the ratio the greater the weathering, bearing in mind that in parent materials such as quartzite the ratios even in the lower layers may be high to begin with, although the fine clay in most drifts tends to be fairly rich in both aluminium and iron oxides.

Together with the loss of iron (Fe_2O_3) and aluminium (Al_2O_3) oxides there is a loss of exchangeable bases and the upper layers become more acid. The pH values in Table I show a decrease in acidity with increasing depth. There is rarely any marked rise in bases in the lower layers unless the soil is derived from a parent material rich in bases, although changes may be noted if the degree of unsaturation (i.e. the percentage of hydrogen in the clay) is worked out.

The values for the exchangeable lime (CaO), magnesia (MgO), and potash (K_2O) may be taken as the amounts of these substances that are readily

available for plants. In the surface layers these values seem high, but this is due to the higher volume per unit weight of material. With equal volumes such values would be much smaller.

TABLE I. *The Adsorbed Bases (in per cent. and m. eq. per 100 g. Soil < 2 mm.), &c., in a Podzol.*

Depth (in cm.)	CaO	MgO	K_2O	H	*Total**	*pH*	*Clay per cent.*	*Loss on ignition per cent.*
0–10	0·031 1·11	0·014 0·71	0·022 0·46	0·042 41·6	—— % 44·1 m. eq.	4·58	—	32·86
10–15	0·018 0·67	0·007 0·37	0·017 0·36	0·028 27·6	—— % 29·2 m. eq.	4·81	14·72	19·13
15–20	0·005 0·18	0·002 0·10	0·006 0·13	0·020 19·7	—— % 20·3 m. eq.	5·03	12·02	12·39
40–50	0·010 0·35	0·001 0·05	0·004 0·09	0·015 14·9	—— % 15·5 m. eq.	4·95	14·61	11·32
60–70	0·007 0·26	0·002 0·01	0·003 0·07	0·007 6·9	—— % 7·4 m. eq.	5·05	7·10	5·94
100–110	0·006 0·22	0·003 0·14	0·004 0·09	0·004 3·5	—— % 4·0 m. eq.	5·27	6·65	4·93

* Including Sr, Na, Mn.

As regards the phosphate figures, the amounts of readily soluble phosphate are usually very small. It is interesting to note that the phosphate is to some extent carried down with the iron and aluminium, for the total amount is much less in the bleached A_2 horizon than in the enriched B. An example is given below.

TABLE II. *The Phosphate Content (per cent.) of a Podzol*

Depth (in cm.)	*Total*	*Available*
0–10	0·20	0·0044
10–15	0·10	—
15–25	0·192	—

In the case of the concealed podzols the data obtained in the various determinations are similar to those of the normal podzols.

The gley podzols and peaty podzols show changes in the composition of the clay fraction similar to those of the podzol, and the exchangeable bases and pH vary in much the same way. The A_2 horizon is usually very strongly bleached and low in plant nutrients, whereas the B horizon is enriched in iron and aluminium oxides and phosphate. The peaty surface is strongly acid, pH values as low as 4 being of common occurrence.

The peaty gleys are certainly strongly leached, but rarely show a horizon

of enrichment, as can be seen from the following data. The soils are usually acid, but somewhat less so than the podzols and peaty podzols. The content of plant nutrients is, however, not very high.

TABLE III. *Silica-Sesquioxide Ratios in the Clay Fractions of a Peaty Gley Soil*

Depth (in cm.)	SiO_2/R_2O_3	SiO_2/Al_2O_3	SiO_2/Fe_2O_3	Al_2O_3/Fe_2O_3
0–5	..	..	..	..
5–10	2·48	2·76	23·2	8·40
10–20	2·38	2·74	17·7	6·45
20–30	2·19	2·66	12·3	4·62
50–60	2·20	2·82	10·0	3·56
120–130	2·18	2·96	8·15	2·76

The surface-water and ground-water gley soils are usually less acid and somewhat richer in plant nutrients than the other soils so far discussed. In the case of the first type this is probably due to the flow of water, which will always contain a certain amount of mineral matter through the upper layers. In the second type there is a rise and fall in the ground-water level so that a part, at least, of any material leached downwards will be brought up again within the reach of plant roots. The variations in the clay fraction from these soils are less regular than in the podzols, but there is usually a loss of sesquioxides from the upper layers, but no obvious zone of enrichment. In the case of the surface-water gleys there is usually a zone of enrichment in bases, as can be seen from the data in Table IV. This particular soil was derived from slates, but when the corresponding type on basic igneous rocks is analysed the rise in bases in the lower layers can be very great (cf. Table V). The phosphate content of these soils is never very high.

TABLE IV. *The Adsorbed Bases (in per cent. and m. eq. per 100 g. Soil < 2 mm.) in a Surface-water Gley Soil*

Depth (in cm.)	CaO	MgO	K_2O	H	*Total**	*pH*	*Clay per cent.*	*Loss on ignition per cent.*
0–20	0·086 / 3·06	0·024 / 1·20	0·016 / 0·34	0·011 / 10·80	% / 15·77 m. eq.	5·37	18·40	18·49
20–30	0·065 / 2·36	0·013 / 0·66	0·006 / 0·13	0·007 / 6·60	% / 10·05 m. eq.	5·60	10·10	5·83
40–50	0·091 / 3·25	0·017 / 0·86	0·008 / 0·17	0·005 / 5·45	% / 10·03 m. eq.	5·90	8·95	4·27
60–70	0·151 / 5·40	0·039 / 1·97	0·010 / 0·21	0·004 / 3·56	% / 11·49 m. eq.	6·85	13·00	4·24
90–100	0·157 / 5·60	0·048 / 2·40	0·010 / 0·22	0·003 / 3·06	% / 11·77 m. eq.	6·28	10·35	3·78

* Including Sr, Na, Mn.

The brown earth type corresponds in acidity conditions to the gley types just discussed, and that, together with its well-drained and well-aerated condition, makes it a very fertile type. As was mentioned in the discussion of the field characters some chemical data are necessary for a complete definition

TABLE V. *The Adsorbed Bases (in per cent. and in m. eq. per 100 g. soil < 2 mm.), &c., in a Brown Earth*

Depth (in cm.)	CaO	MgO	H	*Total*	*pH*	*Clay per cent.*	*Loss on ignition per cent.*
0–15	0·163 / 5·81	0·042 / 2·10	0·017 / 16·85	% / 19·76 m. eq.	5·32	14·15	16·54
15–25	0·058 / 2·08	— / 0·74	0·008 / 8·02	% / 11·04 m. eq.	5·42	9·58	8·65
70–80	0·280 / 9·56	0·060 / 3·01	0·004 / 3·63	% / 16·20 m. eq.	6·63	11·30	3·69
80–90	0·315 / 11·25	0·066 / 3·33	0·003 / 2·93	% / 17·51 m. eq.	6·59	7·60	4·74
100–110	0·344 / 12·30	0·064 / 3·20	0·001 / 1·35	% / 16·85 m. eq.	7·5	4·90	3·84
170–180	0·56 / 20·00	0·089 / 4·43	—	% / 24·43 m. eq.	7·19	5·95	4·01

of the type. This is provided by the clay fraction data. Although there may be a translocation of clay material down the profile there should be no differential movement of silica and sesquioxides; in other words, the values

TABLE VI. *The Adsorbed Bases (in per cent. and m. eq. per 100 g. Soil < 2 mm.), &c., in a Creep Soil*

Depth (in cm.)	CaO	MgO	K_2O	H	*Total**	*pH*	*Clay per cent.*	*Loss on ignition per cent.*
0–10	0·100 / 3·52	0·021 / 1·08	0·026 / 0·55	0·018 / 18·10	% / 24·02 m. eq.	5·41	24·36	17·78
10–20	0·024 / 0·85	0·010 / 0·50	0·014 / 0·29	0·015 / 14·70	% / 16·48 m. eq.	5·19	25·59	11·32
35–45	0·007 / 0·26	0·005 / 0·10	0·007 / 0·15	0·006 / 5·57	% / 6·21 m. eq.	5·16	22·91	7·60
50–60	0·005 / 0·17	—	0·004 / 0·09	0·006 / 6·25	% / 6·65 m. eq.	4·90	9·78	9·85
110–120	0·010 / 0·35	—	0·002 / 0·05	0·002 / 2·02	% / 2·57 m. eq.	5·16	6·81	3·61

* Including Sr, Ma, Mn.

for the silica/sesquioxide ratios should be more or less constant. If the soil is a sandy one Tamm's oxalate extract may be used to show a relative constancy in the amount of the inorganic gel complex down the profile. An example of the type of clay fraction data obtained is given in Fig. 1. The variations are seen to be negligible compared with those in the podzol.

The brown earths on basic rocks are usually quite rich in plant nutrients (Table V) and the rise in the lower layers is as great as in the surface-water gleys derived from the same parent material. The creep soils are usually much poorer in plant nutrients, especially when they are derived from slates and other acidic rocks (Table VI).

SUMMARY

A description is given of some of the soil types occurring on forest ground in north-east Scotland. These include podzols, peaty podzols, peaty gleys, surface- and ground-water gley soils, and brown earths. The various kinds of chemical analyses used in studying the soils are then described and examples of the data obtained and how these are interpreted are given.

CHOICE OF TREE SPECIES IN THE NORTH-EAST OF SCOTLAND ON THE BASIS OF SOIL AND VEGETATION TYPES

BY PROFESSOR H. M. STEVEN

INTRODUCTION

In a recent issue of this journal[1] the author has discussed the criteria which have to be taken into account in the choice of species for afforestation. The contributions in this journal by Drs. Fraser and Muir are based principally on a detailed vegetational and soil survey of an extensive area near Huntly, Aberdeenshire, embracing two Forestry Commission afforestation areas, Clashindarroch and Bin Forests. There were no woods in recent times on Clashindarroch, except limited areas of natural birch, until afforestation began in 1930. The Bin carried a crop of conifers which was cut during and immediately after the war of 1914–18. No statistical data are available for this crop. The Forestry Commission started reafforestation in 1926. Most of the woods in the surrounding country are Scots pine and European larch, frequently in mixture, with small areas of Norway spruce, sometimes in mixture with Scots pine. Except in the location of spruce on the moister sites, there does not appear to have been close correlation between choice of species and soil and vegetation types. It was thought, therefore, that it might be of interest to describe the practice followed in the choice of species during the period 1934 to 1938 at Clashindarroch and Bin Forests on the basis of the vegetation and soil types as defined by Drs. Fraser and Muir respectively. The site conditions at these forests are described in detail in a recently published paper.[2]

BASIS OF CHOICE OF SPECIES

As discussed in the paper in this journal already referred to, many considerations have to be taken into account in the choice of species. On this occasion consideration will only be given briefly to three:

(*a*) *Vegetation Type.*

Vegetation type as an indication of the suitability of a site for a given species has already been referred to by Dr. Fraser. Another aspect of major importance is the direct influence of vegetation type on the tree crop through its influence on local climate, competition, and leaf litter until canopy closes. Thus hardy, deep rooting, and pioneer species such as pine are little influenced by vegetation type, except by competition on grassy types. On the other

[1] *Forestry*, xii, 1938, 93–100.

[2] *Transactions of Royal Society of Edinburgh*, vol. lx, pt. 1, No. 8, 1939–40: 'The Soils and Vegetation of the Bin and Clashindarroch Forests'. By A. Muir and G. K. Fraser. With Notes on Afforestation by H. M. Steven.

hand, the more tender, shallow rooting, spruce is markedly influenced by vegetation type and is particularly sensitive to the nature of the leaf litter of the type, being stimulated by the litter of meadow, grassland, and flush types, and checked on most heath types unless special treatment is given. It is probable that in the choice of species for afforestation in this country we may have been unduly influenced by ease of establishment of species on given vegetation types. When these direct influences of vegetation types disappear on closure of the canopy, soil factors tend to become more important for continued growth. In choice of species, therefore, soil types should be studied equally with vegetation types, because the latter may not fully reflect the former.

(*b*) *Soil Type.*

Soil types as described in the paper by Dr. Muir provide information of silvicultural importance in the choice of species, not only on the influence of soil type on the crop, but of the crop on the soil type, thus giving some reality and precision to the old dictum of the 'maintenance of fertility'. For example, it is considered that pure crops of spruce should be restricted to relatively fertile soils not of low base status, because on such soils accumulation of raw humus is less likely with consequential decline in fertility.

The modern soil type epitomizes the story of the processes that have gone to make it, for example the movement of water and bases, &c., tendency or otherwise to form raw humus, aeration, and activity of worms, &c. The nature of these soil processes may be of greater silvicultural importance than intrinsic chemical fertility. Data on the latter will be of greater value when more is known about the nutrient requirements of our different species.

(*c*) *Economic.*

The aim, economic as well as silvicultural, must be to produce healthy, well-grown crops. When existing knowledge and experience indicate that more than one species will do this, then the one which will give the best return should be selected, because this aspect should also take into account the relative demand for the different timbers. Thus spruce gives a better return than larch which, in turn, is more profitable than Scots pine. To select the latter when the first can be selected is, therefore, a mistake, unless the known influence of a crop of the more profitable species on the particular site is deleterious, and thus will lead to reduced profitableness of future crops.

THE PODZOL

The points of silvicultural importance in this soil type are as follows:

(*a*) There has been a loss of exchangeable bases, phosphates, aluminium, and iron from the surface horizons. A deep-rooting species will tend, therefore, to slow down this process by a reverse cycle compared with a shallow rooting species. The degree of surface leaching is of importance.

(*b*) Typically the A_0 horizon is a raw humus. This layer of raw humus is

an important factor in the rate of podzolization, hence a tree crop that also produces raw humus is less desirable than one that does not.

(*c*) The presence or absence of hard pan. Hard pan not only impedes deep rooting, restricting root development to the leached horizon, but also impedes water movements, tending to waterlogging in winter and drying out in summer.

(*d*) The general level of chemical fertility varies depending on the parent material, but is not generally high.

Normal Podzols. On strongly podzolized soils, without hard pan, and with low intrinsic fertility, for example where the parent material is sand or gravel or quartzite, there is no alternative to Scots pine. On this type good crops of Scots pine have been grown producing slow grown, good quality timber.

On less strongly podzolized soils of somewhat higher intrinsic fertility, for example on schists at Clashindarroch, the growth of more profitable species than Scots pine has been attempted. On steep and well-sheltered slopes with dry grass heath vegetation European larch has been used. At higher elevations and on the moist heath series with a peaty surface Japanese larch has been planted. In the initial stages the results have been promising, but it remains to be seen whether Scots pine would be preferable on these sites.

Podzol with hard pan. In this region this soil type is generally associated with moist heath types and flat ground, such as ridges and shelves on slopes. Without special treatment there is no alternative to Scots pine, and the growth of this species is poor. At Clashindarroch the present practice is to plough, using a caterpillar tractor and a heavy plough. A deep single furrow is taken out at an espacement, centre to centre, of $4\frac{1}{2}$ to 5 feet. Generally, the pan is ruptured at least in places, and there is evidence of the weathering of the pan from the ruptured edges. Planting is done on the loose soil on the side of the furrow. This treatment mixes the different horizons together, tends to stabilize water relations during winter and summer, and improves aeration. The vegetation type is influenced, at least temporarily, grasses increasing in amount and luxuriance.

The best species for this type thus treated is still the subject of experiment, but half-and-half mixtures of Scots pine and European larch and Scots pine and Sitka spruce are promising. A deep-rooting species, at least as a constituent of a mixture, appears desirable for the reason already stated. Sitka spruce is used because it is resistant to exposure, and this type is found, in part, on exposed sites and is used in preference to Norway spruce, because it is less likely to go into check if the heath vegetation re-establishes itself on the plough furrow before the closure of canopy.

Gley Podzols. The area of this type within the afforestation areas is small. Its water status indicates a spruce, but it is associated with a heath vegetation, and the establishment of spruce without special treatment would be difficult. Scots pine has been used on it, but success might be secured using Sitka spruce with draining or turfing or ploughing.

Peaty Podzols. This soil type generally carries a sub-moorland type of

vegetation, and in this region it is almost always associated with an iron pan. It is, therefore, a difficult type and doubtfully plantable unless with special treatment. There is an example of a middle-age Scots pine plantation on this type adjoining the Balloch section of Bin Forest. It was planted after close and deep drainage. The rate of growth has been slow and its condition only fair. In recent years Sitka spruce has been used both on the natural surface and on turfs on this type. After seven years these trees are still in check and success is doubtful. Japanese larch has also been tried, also with indifferent results. The most hopeful treatment is deep contour drainage combined with ploughing as already described, where practicable. The best species is uncertain, but a pine-Sitka spruce mixture has possibilities on silvicultural and economic grounds.

GLEY SOILS

The principal point of silvicultural importance in these soil types is their high-water content which may fluctuate both seasonally or over a period of years. For example, when a tree crop is clear-cut on a ground-water gley soil, the water table tends to rise, increasing the amount of drainage required for re-establishment of the crop.

Ground-water Gley Soils. This is an important type on basic drift at the Bin and carries a predominantly grass meadow *D. caespitosa* vegetation type. Norway spruce was used with success on this type in the previous crop on the Bin, and it has been planted again. Of coniferous species it appears ideal; the soil type has the requisite moisture status, and where derived from basic parent material raw humus development is unlikely. The type requires deep contour drainage to lower the water table, and such drains will require to be maintained to keep the crop stable, unless the ground-water level falls naturally through increased transpiration of the tree crop when in canopy. Turfing accelerates establishment.

Where the parent material is less basic, for example slates, the associated vegetation type may be a grass heath. In such instances Sitka spruce will be more easily established than Norway spruce.

Surface-water Gley Soils. The associated vegetation types are generally heath-flush and moist heath. Contour drainage is also necessary in this type, although the drains need not, in general, be so deep. Both Norway and Sitka spruces have been used. On the balance of evidence the latter is better from the point of view of early establishment. On grass-flushes associated with this soil type Norway spruce can be safely used.

THE BROWN EARTH

The points of silvicultural importance in this soil type are as follows:

(*a*) The distribution of plant nutrients is more uniform through the different horizons than in a podzol.

(*b*) Raw humus is either not developed or to a much less extent than in

a podzol. Typically, earthworms are active in mixing the different horizons, hence aeration is usually good.

(*c*) While intrinsic fertility varies with parent material, it is typically higher than in a podzol.

These characteristics enable a wider range of species to be considered, including the more exacting.

Dr. Muir has defined three sub-types.

Normal Brown Earths. This type has been planted at the Bin Forest with a range of species, including larches, spruces, and Scots pine. These may be selected on the basis of varying vegetation types. Norway spruce is suitable for the limited areas of grass meadow associated with this type. On grass heaths Sitka spruce starts slowly but maintains its needle colour. At this forest the type is restricted mainly to knolls and ridges, and it is considered that such are not suitable for larches unless fully sheltered. When carrying a dry heath type, Scots pine has been used, and is probably the only safe species.

Creep Soils. These soils, mainly at Clashindarroch, are generally on steep slopes. The associated vegetation types are zoned and the choice of species has been correlated with these. On the lower slopes and on the dry heath series, *Calluna–Erica cinerea*, dry *Calluna–Vaccinium myrtillus*, and dry *Calluna–Arctostaphylos*, European larch has been used. These are not typical vegetation types for European larch in most parts of this country, but the soil type and initial results appear to justify the choice. On the upper slopes and on moist *Calluna* series Japanese larch has been used.

On the evidence to date these soils appear too dry for spruces, while their relative fertility, in a broad sense, makes pines undesirable on economic grounds.

Brown Earths with Gleyed Horizons. This type at the Bin has a high moisture and base status, hence spruces are indicated. Norway and Sitka spruces have been differentiated on the basis of vegetation type, that is ease of establishment, the former on grass meadow, and the latter on grass heath.

SUMMARY

The choice of tree species at two Forestry Commission areas, Clashindarroch and Bin Forests, Aberdeenshire, is discussed on the basis of the soil and vegetation types defined by Drs. A. Muir and G. K. Fraser. The points of silvicultural importance in the different types are stated.

SOCIETY'S AND OTHER NEWS

OBITUARY

The late Joseph Burtt Davy, M.A., D.Phil. (Oxon.), Ph.D. (Cantab.).

It is with deep regret that we have to record the death of Dr. Burtt Davy. Few men were more deeply immersed in the subject of their life-work or gave themselves more completely to its service. Moreover, his gentleness, charm, and eagerness to help make his passing a severe personal loss to his friends.

When Dr. Burtt Davy became Lecturer on Tropical Forest Botany at the Imperial Forestry Institute, Oxford, in 1925, he had already an unusually wide and varied botanical experience, both in South Africa and the United States of America. He began his career as a botanist in California about fifty years ago, and held various appointments there, both academic and state, with a short spell as Assistant to the Director of the Royal Botanic Gardens, Kew. In 1903 he became chief of the Division of Botany in the Department of Agriculture, Pretoria. During a period of ten years there, he carried out important work both in applied botany, e.g. on maize, and on the flora of the Transvaal.

His contributions to forest botany and forestry date, however, from his coming to Oxford. He built up his department at the Imperial Forestry Institute; created an important herbarium, particularly of tropical forest trees; and inspired many of the men who passed through his hands with an interest in and knowledge of systematic botany which in turn has borne fruit in a great extension of knowledge of the tree flora in many colonies, particularly in Africa. During this period also he travelled widely in Africa. The results of this period are seen, in part, in the series 'Forest Trees and Timbers of the British Empire', which he edited in collaboration with Dr. Chalk.

His interests, however, were not confined to overseas. He did important work on the systematics of the willows and elms in this country, and some of his contributions on these subjects were published in this journal.

Dr. Burtt Davy was interested in botany as a whole, scientific, aesthetic, and practical. This was shown particularly in his gardens. He made beautiful, interesting, and productive gardens in California, South Africa, and at his home, Shotover Furze, Headington, Oxford. In some small measure this garden expressed himself and his life-work.

REVIEWS

Colonial Forest Administration. By R. S. Troup. Oxford University Press, 1940. Price 35*s*.

Review by W. M. McNeill

This is indeed a monumental volume, massive and permanent. As Professor Troup explains in his preface, the book has grown out of lectures on forest policy and administration, and it has grown well. This work was written primarily 'to be of general use to administrators', but also 'to be of use to forest and agricultural officers as well as to others interested in forest administration'. Any of us who have had to struggle with problems of forest administration, and battle against ignorance and opposition on the part of the framers of policy, will wish that such a book as this had been in our hands

for guidance and support. The voice of the colonial forest officer is often the voice of one crying in the wilderness, but foresters cannot be absolved from mistakes, lack of co-operation, and tactlessness, and there is often a genuine desire on the part of administrators to understand the problems of colonial forestry. There can now be little excuse for ignorance or stupidity on either side.

The first impression that this closely packed book gives is something like that which one experiences on entering a building of historic interest filled with exhibits. There are corridors from which many rooms open, each furnished with interesting and attractive collections so that at first one wonders what to examine most closely. Troup's last book is much more than a catalogue of exhibits: it is a storehouse of information.

The book is divided into two parts: the first, comprising 319 pages, deals with what the author has called 'General Principles'; the second, covering the remaining 157 pages, deals with the historical development of forest policy and administration in those various Colonial Dependencies which have a separate forest department.

Part I starts with a sub-section entitled 'What is Forestry?' and the larger portion of the book gives the answer with that thoroughness so characteristic of all Troup's writing. The field covered is enormous and includes chapters on Utility of Forests, Products of the Forest, Indirect Utility and Influence of Forests, Effects of Forest Destruction, Measures of Protection and Conservation, Character and Distribution of Forests, Forest Reservation, Forest Protection, Forest Organization, Formation, Regeneration and Tending of Forest Crops, Production and Consumption of Wood, Forest Exploitation, Forest Ownership, State Control and Assistance, Forestry and Agriculture, Forestry and Mining, Forest Finance, Forest Legislation, Forest Administration, Forest Education, Research, and other Activities, and Enunciation of Forest Policy.

Troup is the master compiler; here are the collections most completely arranged. But he is also a master of clear expression; here is a case presented convincingly and with delightful clarity. The author's intense hatred of superficiality and his inability to do things by halves explain the length of this statement of general principles.

No fault can be found with the wealth of information, only perhaps that it is a little bewildering, but now and again one wishes that the author would throw off his reserve and give us more outspokenly his opinion based on such wide and unique experience. For example, the bare statement is made that 'there is no Forest Advisor to the Colonial Office' (pp. 282–3). Here and there he does strike out, as, for example, when he denounces roundly the iniquities of so-called selective logging in the tropics. He is emphatic on the subject of reservation; 'nothing short of permanency of tenure will secure the necessary continuity of management over long periods of time or justify expenditure on the demarcation, protection and management of a forest' (p. 117). He stresses the importance of an efficient native staff; ' a competent and reliable native subordinate staff is essential to success' (p. 287). He bestows his blessing on the unification of the Colonial Forest Service.

Sometimes it would appear that his restraint makes him stop short and evade the bald and unpleasant facts. For example, when dealing with the relationship between the head of a forest department and a non-technical administrative official, no mention is made of the not infrequent trouble caused by a minister using his political influence or bias to override sound and disinterested technical advice. Some of the terms used are unusual, such as 'Forest Organization' (ch. x), by which is meant 'the bringing of a forest into regular working' (p. 160), and 'Primary' and 'Secondary Production', which attempt to differentiate between 'the growing of timber' and 'the handling of

it from the time the tree is felled to the time the produce reaches the consumer' (p. 179). The terms 'Disafforestation', 'Deforestation', and 'De-reserve' are stated to be the official language for 'the process of formally relinquishing a forest reserve' (p. 136), the term 'unreserve' would appear both commoner and nearer to the meaning.

Part II provides interesting comparative historical information regarding the development of forestry in different parts of the Colonial Empire up to the present time. This part of the book will not have the permanency of the first part and it is to be hoped that some of the records will change rapidly and soon.

It is unfortunate that the two financial experiments with a Forest Trust—British Guiana and British Honduras—were not more successful. It is not clear why Nyasaland should have the largest space, 10 pages, in this gallery of special collections, while such large and important forest colonies as Nigeria and Malaya are considered more briefly. More surprising is it to find that, at least in the case of Ceylon, the information regarding legislation is not quite up to date.

This is not the end of the book; valuable appendices are added dealing in comparative detail with such subjects as Forests and Water Supply, the Control of Tsetse Flies, Legislation in Regard to Protective Forestry, Mining Laws and Timber Rights, and Colonial Laws dealing with Forestry.

A series of excellent photographs, principally by the author, add still further to the value of this book and reveal Professor Troup as an artist in addition to his other attributes.

The book is beautifully printed and produced by the Oxford University Press. The index, although not in great detail, should suffice for most practical purposes of reference. The greatest credit is due to those who saw this work through the press.

Professor Troup died before this book was published. During his life of intensely hard work he filled several gaps in our forest literature and he has given us some great books. In some respects at least his last book is his greatest, for it will interest and influence more people than any he wrote previously. Many forest officers scattered over the Colonial Empire owe most of their forestry knowledge to Professor Troup. He was more than a teacher, he was a very kind and sound advisor. In this last memorial he will continue to live and to give help and knowledge to many. In the middle of war and destruction it is a deep source of hope to find something which is living and permanent and which will, without doubt, make things better in the future.

Beetles Injurious to Timber and Furniture. Forest Products Research Bulletin, No. 19. Dept. of Scientific and Industrial Research, Forest Products Research Laboratory, Princes Risborough, August, 1940.

Review by R. N. Chrystal

THIS bulletin is a completely revised edition of a publication entitled *Beetles injurious to Timber*, which was published by H.M. Forestry Commission in 1928. The new edition has many advantages to draw upon to enable it to put up a convincing case for reissue. The first of these is the decade or more of work on the biology and economics of timber insects carried out at the Forest Products Research Laboratory at Princes Risborough by Dr. R. C. Fisher and his assistants. All sections of the bulletin show evidence of this, and the illustrations, which have been much increased in numbers, also furnish proof of the up-to-date information brought together in these pages. The

general form of the bulletin resembles that of its predecessor, the first portion dealing with the longhorn and pinhole-borer types of borer, and giving new details of recent discoveries relative to the appearance as pests of several species of longhorn beetles in various parts of Great Britain. The greater portion of the latter part of the bulletin is concerned with the powder-post beetles of the family Lyctidae, and the furniture beetles of the family Anobiidae. Here all the results of the most recent research have been carefully brought together, and the reader who takes a practical interest in these insects will do well to study these pages with care from three points of view. Firstly, as regards the methods of identifying these insects and their work; secondly, as regards their natural distribution in woodlands; and thirdly, as regards the most practical methods for their control here recommended. The careful and guarded language used by the author in discussing control measures is a measure of the faith which may be placed in his conclusions.

The bulletin ends with a short account of some lesser-known timber beetles, the *Cossonidae* wood-boring weevils, and the wharf-borer, *Nacerda melanura* L. The bibliography gives a good list of the most important recent literature.

Recent Contributions from the Botany Department of Leeds University.

Review by S. H. Clarke

FORESTERS owe a considerable debt to Professor J. H. Priestley and his co-workers at Leeds for the contributions they have made during the last twenty years to knowledge of the processes which go on within the bark of the living tree. Refusing a blind acceptance of certain statements in the standard works, they have brought a fresh viewpoint to the re-examination of a number of old problems, and in consequence have made some interesting discoveries. Much of their work has been recorded or reviewed in earlier numbers of this journal, but several new papers have recently appeared.

Many botanical text-books gloss over the behaviour of the cell-wall at the time of cell division by representing it diagrammatically as a single line; the division wall across the telophase spindle is then represented as joining opposite sides of the parent wall, and thus dividing the cell into halves. With a more accurate representation the question arises as to how a cambial cell surrounded by middle lamella *and a primary wall* produces by successive divisions a tissue in which the middle lamellae form a continuous system. By examination of a variety of tissues, Professor Priestley and Miss Scott (1) have obtained evidence that, when the protoplast divides into halves, each half is completely surrounded by a new wall. As these halves expand, the original containing wall is ruptured. The wall is so thin that it had escaped recognition until very recently.

W. R. C. Handley (2) refers to the long-standing problem of the ascent of sap, and reviews some of the main arguments for and against the vitalistic hypothesis. By controlled chilling of woody shoots of ash and sycamore in the critical range of temperature within which protoplasm is very sensitive to relatively small changes, he was able to show that translocation may be inhibited by a fall in temperature of 1° C., although the viscosity of the liquid in the vessels is not greatly changed, while the requirements of roots and leaves remain unchanged. It is concluded that 'This would appear to indicate that vessels and other dead xylem elements . . . are unconnected with water availability or conduction except in the role of reservoirs.' While there are still objections to a theory of the ascent of sap entirely dependent on a living system, it would appear difficult to escape the conclusion that living cells play an important part in that ascent.

Considerable attention has been attracted in recent years to studies of the plant cell-wall, and Dr. Preston, whose original work has formed no mean contribution to advances in this field, has reviewed the current position for the benefit of botanists (3). It is to be feared that many botanists will find the paper rather heavy going, but they will also find perseverance well rewarded. The construction of the chain-like molecules of cellulose is described in some detail, reference is made to the work of the chemists and physicists whose investigations have been mainly instrumental in furnishing the picture he presents. The general conception of the plant cell-wall as composed of ultra-microscopic chain-like molecules of cellulose will no doubt be familiar to most readers of this review. Dr. Preston describes how these chains are united in ill-defined bundles which correspond to the classical micelles of Nägeli. The micelles form a more or less loofah-like system in the spaces of which incrusting substances such as pectin and lignin are deposited; hemi-celluloses, on the other hand, such as xylan, are almost certainly included in the micellar chains themselves. There is a very interesting account of the parts played by X-rays and polarized light in elucidating cell-wall structure, and a particularly interesting description of 'form double refraction'. The characteristic layers of the cell-well are described and their significance is discussed. Reference is made in the review to the detailed study of the vessel wall which is more fully described on another paper (4), and the publication of the study of the tracheid wall as a single spiral complex (5) is foreshadowed.

Dr. Preston's papers are particularly interesting in making two important suggestions. Evidence is furnished which suggests that the arrangement of the cellulose threads in the cell-wall is dependent on the configuration of the protein molecules at the cytoplasm–wall interface. For this and other reasons Dr. Preston objects to the increasingly prevalent conception that the cellulose chains of the primary wall occupy a flat spiral, somewhat resembling that of the wire reinforcement of a hose pipe, while in the bulk of the wall they are approximately parallel to the axis of the cell. Evidence for such a difference of arrangement has been obtained principally by examination of the wall by polarized light and by observation of chemically swollen material. It is pointed out, however, that not only are these observations susceptible of other interpretations, but they conflict with the evidence supplied by X-rays. Dr. Preston concludes that so far as ordinary conifer tracheids are concerned, within any given segment of the wall, the inclination of the cellulose threads is practically constant in the successive primary and secondary walls. A diagram is given (5) in which the differences in the optical properties of the three layers commonly present in the secondary wall are explained by an arrangement of cellulose chains, direction of which is subject to considerable variation within the thickness of the wall, but the projection of which at the surface of the wall is uniformly inclined to the plane of the axis.

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